

**THE AIR FORCE MANUFACTURING TECHNOLOGY (MANTECH)
TECHNOLOGY TRANSFER METHODOLOGY AS EXEMPLIFIED
BY THE RADAR TRANSMIT/RECEIVE MODULE PROGRAM**

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ABSTRACT

The Air Force Manufacturing Technology program is involved with the improvement of radar transmit/receive modules for use in active phased array radars for advanced fighter aircraft. Improvements in all areas of manufacture and test of these modules resulting in order of magnitude improvements in the cost of and rate of production will be addressed, as well as the ongoing transfer of this technology to the Navy.

MANUFACTURING TECHNOLOGY BACKGROUND

Since its inception in 1947, the goal of the Air Force Manufacturing Technology (MANTECH) program has been to enhance productivity, increase quality, and reduce life-cycle cost of weapon systems. Contractual projects are application oriented, designed to demonstrate, validate, and implement manufacturing processes for use by the aerospace industry and the Air Logistics Centers of the Air Force Logistics Command.

MANTECH investments address high-payoff problem areas in all industry sectors producing and repairing weapon systems and support equipment for the Air Force (AF). Problems addressed are generic in nature, applicable to virtually all manufacturers in any industry sector and to multiple weapon systems. Efforts address all levels of industry from large prime contractors to material and parts vendors as small as 20-person shops.

MANTECH investments are made to accelerate and broaden the implementation of production concepts and techniques proven feasible in the research and development community. Contracts are awarded to private industry on a competitive basis and provide focus, direction, and "seed money" in manufacturing technology areas that offer potentially high payoff but are beyond the normal risk for industrial investment. High payoff can be measured not only in direct production savings but also in quality which improves safety, serviceability, and readiness. Projects funded by MANTECH generate and disseminate technical information and technical knowledge. Industry, however, is responsible for direct implementation costs and capital equipment procurements.

The Wright Laboratory's Manufacturing Technology Directorate (MT) is organized into four divisions: Electronics, Integration Technology, Processing and Fabrication, and Industrial Base Analysis; and three offices: Concurrent Engineering, Business Integration, and Defense Production Act.

The Electronics Division (MTE) consists of the Components Fabrication and Assembly Branch, which pursues Air Force needs in solid state microwave systems, microwave tubes, infrared detectors and other energy conversion components, and the Materials and Device Processes Branch, which manages programs in semiconductor materials, digital integrated circuits, interconnections, inspections and tests.

The effective integration of processes, systems, and procedures used in the production of aerospace systems using computer technology is managed by the Integration Technology Division (MTI). Under its auspices are the Information Management Branch, which is actively involved with information management, information sciences and integration, and the Implementation Branch, whose technology areas include computer integrated manufacturing, engineering design, operations research, and material handling and assembly. The Integration Technology Division combines design, manufacturing, and supportability functions within the same organization.

The Processing and Fabrication Division (MTP) manages programs to improve structural and nonstructural materials processing and fabrication. Within this division, the Metals Branch directs the manufacturing methods program for metals and metal matrix composites processing and fabrication. The Nonmetals Branch directs the manufacturing methods programs, which include all manufacturing processes for producing and utilizing propellants, plastics, resins, fibers, composites, fluid elastomers, ceramics, glasses, and coatings.

The objective of the Industrial Base Analysis Division (MTA) is to act as focal point for the USAF industrial base program for productivity, responsiveness, and preparedness planning. They coordinate annual Air Force Systems Command and Air Force Logistics Command data into the U.S. Air Force production base analysis, recommend investment strategies for the MANTECH element, and provide industrial base analyses and technical assistance.

The Concurrent Engineering Office (MTR) plans, initiates, coordinates and manages programs addressing Integrated Product Development (IPD) which span a broad spectrum of disciplines, including engineering design, manufacturing, quality assurance, and logistics support. This office is also responsible for managing the Manufacturing Science program for the Directorate which focuses on establishing a science base from which to transition new technologies for further refinement by the Manufacturing Technology programs.

The Business Management Integration Office (MTX) coordinates and consolidates the investment strategy for the Manufacturing Technology Directorate. This office also plans, coordinates, and manages the Repair Technology Program (REPTECH), provides technical guidance in the evaluation of proposed Industrial Modernization Incentives Program (IMIP) projects, and is the manager of MANTECH's technology transfer and benefits tracking programs.

The Defense Production Act Office (MTD) serves as the program office for Air Force Title III programs, which establish or expand domestic production capacity for materials that are considered critical to DOD. Title III accomplished this by providing domestic industry with incentives in the form of purchases and purchase commitments for materials.

The Air Force Manufacturing Technology Directorate has recently undertaken a comprehensive development and implementation effort for an internal technology transfer and benefits tracking program. Technology transfer is government fostering of technologies and processes with the interest of industry adoption. MANTECH projects are inherently structured to address generic problems and utilize a particular weapon system for demonstrating first implementation. This process benefits large DOD prime contractors with significant manufacturing technology enhancements. Substantial improvement in technology transfer without a corresponding increase in the AF investment requires a focus on the entire industry, not the just the primes. Increasing the capabilities of the U.S. generic manufacturing base (Air Force Air Logistics Centers, subcontractors, vendors) will provide the AF with a sizeable return on investment and help maintain and improve the DOD and commercial industry posture and position in the global manufacturing arena. Successful technology transfer is a goal of the MANTECH program.

One example of a program within the Electronics Division with technology transfer potential both within the DOD industrial base and for commercial purposes is the Radar Transmit/Receive (T/R) Module Program.

RADAR TRANSMIT/RECEIVE MODULE PROGRAM

Active element phased array systems utilizing transmit/receive (T/R) modules are considered to be one of the most promising technologies for future ground-based, airborne, and space-based radar applications. Advanced aircraft require active arrays for radar systems for detecting and tracking multiple targets, detecting stealthy aircraft, and for the benefits of improved reliability, lower maintenance costs, and reductions in size and weight. For example, the current F-16 radar system has a 100 hour Mean Time Between Failure (MTBF), while the proposed configuration using T/R modules would have an MTBF of between 80,000 and 100,000 hours. However, the T/R module is the major cost driver for an active phased array system. An average phased array system for an aircraft would require 2000 modules. At a current cost of \$8000 per module, the cost of modules for one radar would be in excess of \$16 million! Because of the high cost and quantities required for these modules, Air Force program offices developing new aircraft are reluctant to commit to an active element phased array design.

Feasibility and validation T/R microwave modules for many new systems have been built in small prototype quantities or very limited production quantities, and their use has been largely limited to ground-based systems to date. Costs are extraordinarily high as a result of complex designs, the need for precision fabrication, the costs of parts and materials, and the general lack of adequate assembly, test and automation equipment. This program is needed to reduce T/R module costs and demonstrate that the technology is producible for the weapon systems of the future. The two goals of the programs are affordability; a cost goal of \$400 has been established, and volume production; 1000 modules/day will be necessary for full scale production of aircraft radar.

The development of new manufacturing technology for radar T/R modules carries the possibility of more than one successful concept. For this reason, two contracts were issued for a 42-month technical effort in April 1989. One contract was awarded to Texas Instruments and Westinghouse in a joint venture. The second contract was awarded to Hughes Aircraft. These manufacturers represent a significant portion of the airborne radar industry, and were the two competing contractors for the F-22 radar subsystem. The effort is divided into four phases.

Phase I of the program involves definition of the baseline module specification. Phase II defines materials and identifies manufacturing issues related to performance, producibility, and cost and proposes a T/R module configuration that meets the baseline requirements. Phase III will produce a module prototype that addresses pertinent design for manufacturability and economic issues. Phase IV will establish the manufacturing processes and controls to demonstrate the production capability for large quantities of low cost T/R modules.

Currently, the two programs have proceeded through Phase I and are involved in Phase II activities. The specific cost drivers within the T/R module production have been identified as the MMIC chip set, test of the completed module, the module housing, automation of the process, and the rework required to meet specifications. Each of the two efforts is exploring a different set of technologies and applications to address these drivers.

The Texas Instruments/Westinghouse effort involves the transmitter and receiver modules packages in separate, hermetically sealed packages. A U.S. vendor supplied metal three-piece housing is used, consisting of a base, ring, and frame/lid. The module is developed on a multilayer thin film substrate, with integrated RF/DC feedthroughs and wire bond interconnects. A combination of epoxy and solder is used for chip attachment; epoxy for the low power portions, and solder for the high power amplifier. Some of the benefits of this approach include reduction in feedthroughs from 4 to 2, elimination of manual placement by use of chip capacitors compatible with automated assembly equipment, use of low cost flex circuit for the bias and logic interface. Test times have already been reduced over 80% per module - a necessity to meet required throughput and decreased cost goals.

The Hughes approach involves a one package GaAs-based transmitter/receiver. Digital control is provided through a separate package. The package uses a Low Temperature Co-fired Ceramic (LTCC) integrated housing and substrate, and a flip chip mounting. The project has already reduced parts count and interconnects by a factor of four, and Hughes is feeding results from their involvement in the DARPA Microwave Millimeter Wave Monolithic Integrated Circuit (MIMIC) program into this effort to drive the cost of GaAs chips down by a factor of 3 to 4.

At the end of Phase IV of this program, in late 1993, at least one version of a T/R module which meets the requirements of advanced radar systems requirements will be configured for high volume manufacturing. The module will exhibit the following manufacturing qualities: lower parts count than previous revisions (from 135 to 32 parts); fewer fabrication process steps (from 98 to 20 steps); producibility (will demonstrate a large quantity module built within a 30-day calendar period). The module cost will be driven down from \$8200 to a projection of less than \$400 and a reliability of greater than 125,000 hours Mean Time Between Failure (MTBF) is projected.

In addition to the basic process improvements, efforts are also underway to concurrently transfer this technology to ITT, another radar manufacturer, in support of Navy requirements. This technology transfer activity involves identifying and defining specific Air Force developed technologies within the two programs that have the potential application to manufacturing of Navy C-Band T/R modules. Then, through a combination of hands-on instruction, site visits, and implementation assistance from the two Air Force contractors, the necessary technologies will be transferred to ITT's production facility.

Through this program and others like it, the Air Force Manufacturing Technology Directorate expects to continue its long standing track record of providing high return on investment technologies in the production and repair of Air Force weapon systems.